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CONTENTS

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The manipulation of irrigation and drying-off schedules of sugar cane to increase sucrose yields.

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Perusal of sugar cane production records in the sugar cane belt located in the lowveld of Zimbabwe indicated that sucrose yield was generally lower when water was abundant compared to drought years. It was therefore hypothesized that sucrose yield would be increased by restricting irrigation compared to current practice. Three irrigation treatments, namely, irrigating at crop factor 1.00 (current practice), irrigating at crop factor 0.85 and, irrigating at crop factor 0.70, were tested in factorial combination with three drying-off treatments: drying-off to 55 per cent moisture depletion (current practice), to 60 per cent and, to 65 per cent moisture depletion. The experiment was laid out as a split-plot. A standard cane variety NCO 376, which forms 97 per cent of the area under cane was used in the experiment. The results clearly indicated that it is possible to manipulate sucrose concentration and hence sucrose yield by restricting the amount of water applied to the sugar cane crop. Highest sucrose concentration and sucrose yield per hectare was achieved by irrigating at crop factor 0.85 and drying-off to 60 per cent depletion. It is concluded that inducing mild stress by restricting water to levels that do not fall below crop factor 0.85 will increase sucrose yield in the lowveld.

Keywords: Sugar cane, restricted irrigation, sucrose concentration and yield.

Introduction

Sugar cane, (*Saccharum officinarum* L.) is the world's most widely cultivated commercial source of sugar, with Zimbabwe supplying 26 per cent of the world's needs and 100 per cent of local needs (Farai, 1996). The country's sugar cane belt situated in the south east lowveld of Zimbabwe is drought-prone and receives on average 500 mm of rainfall (Department of Meteorological Services, 1981). This is by far too low for sugar cane production which requires a total of 1 950 mm of water per season (Zosch, 1988). Production of sugar cane therefore relies heavily on irrigation. However, sucrose yields have been compromised by lack of good irrigation management. This has largely been the result of excess application of water to cane plants and inadequate drying-off schedules (Zihary, *et.al.*, 1989).

The differences in sucrose yield between rainy and drought years is striking. Higher sucrose yields (mean of 13.78 per cent ERC) were obtained in low rainfall years (1982 to 1992) compared to a mean of 11.52 per cent ERC in wetter years (1970 to 1980) (Farai, 1996). This would seem to suggest that restricting irrigation may increase sucrose yields and profits to farmers. Other potential spin-offs from restricted irrigation would be savings in water, thereby allowing an expansion of hectarage under sugar cane which is currently limited by inadequate water supply.

Sugar cane will remain immature if growth conditions, particularly concerning water, are not limiting (Arnold, 1993). Imposing water stress forces the crop to store sucrose at the expense of storage tissue development. Cane can be considered mature at nine months of age from a grower's point of view if forced ripening induced by water stress raises sucrose concentration to 14 per cent ERC (Zihary *et al.*, 1989). Low temperatures play an important part in sugar cane maturity and quality. Low temperature retards vegetative growth and promotes sucrose concentration. In principle therefore, the lower the minimum temperature the better the sucrose yield. Low mean daily minimum temperatures experienced annually in the lowveld from April to September allow for natural ripening and high sucrose yield during this period. However, if temperatures are high during this period, low sucrose yields would be experienced. Temperature is, unfortunately, beyond the grower's control. Overcast conditions have a negative effect on sucrose yield (Arnold, 1993) but these rarely occur in the lowveld. The only practical way to control sucrose content would be to manipulate irrigation such that sucrose content is increased or to use chemical ripeners to promote maturity.

The objective of the work reported in this paper was to increase sucrose content by manipulating irrigation and drying-off schedules. It was hypo- thesised that sucrose content would be increased by restricted irrigation and drying-off to a soil moisture depletion level lower than the normal 55 per cent.

Materials and Methods

An irrigation experiment was initiated in November 1995 and completed in August 1996 at the Zimbabwe Sugar Association Experiment Station in the south-east lowveld near Chiredzi. The station lies at 21° 55" S and 19° E at an altitude of 412 metres above sea level. Mean daily maximum temperature is 29.7°C and mean daily minimum is 15.3°C. Mean annual rainfall is 565 mm. The soil at the station, which is typical of the sugar growing estates in the lowveld, is a verti-chromic luvisol.

The test crop for the irrigation trial was a twenty four month old ratoon crop, variety NCO 376. This variety occupies 97 per cent of the area under sugar cane in Zimbabwe (Donald, 1994). Three irrigation frequencies based on crop factors were compared as follows;

Treatment 1: 100 mm applied at 100 mm pan evaporation deficit (crop factor 1.00). This treatment consti-tuted the control as it is the current irrigation practise in the lowveld.

Treatment 2: 50 mm applied at 59 mm pan evaporation deficit (crop factor 0.85).

Treatment 3: 50 mm applied at 71 mm pan evaporation deficit (crop factor 0.70).

Drying-off treatments were: a) depleting to 55 per cent; b) depleting to 60 per cent; and, c) depleting to 65 per cent of total available moisture.

The experiment was laid out as split-plot with irrigation treatments as the main plot factor and drying-off treatments as the the sub-plot factor. All treatments were replicated four times. Each main plot measured 9.2 m x 8.2 m. Sub-plots consisted of four 2.40 m long rows of sugar cane planted 0.60 m apart, with a nett plot of two 1.40 m row sections. An airtight black polythene sheeting was buried 1.8 m between each sub-plot and main-plot to reduce the effects of water movement between plots through seepage. The sugar cane was planted into flood irrigated beds prepared to enable metered amounts of water to be applied to each plot, with adequate drainage installed to dispose of surplus water accumulating on the beds after excessive rainfall.

Irrigation treatments were imposed for a total of eight months. A rain gauge was used to monitor rainfall and a class 'A' evaporation pan for daily evapotranspiration estimation. Drying-off treatments were imposed during the months July 1996 to August 1996. Moisture levels in sub-plots were monitored through gravimetric measurements. The timing of imposition of drying-off treatments was such that all plots could be harvested at the same time. This enabled the removal of age differences amongst the plots.

Routine hand weeding was carried out on all treatment plots. This was to maximise water use efficiency by the cane plants. The ratoon crop received 200 kg/ha single super phosphate (19 per cent P_2O_5) applied as a band following harvesting in June 1995. Ammonium nitrate (34.5 per cent N) was applied as a band at a rate of 450 kg/ha based on soil analysis. This was in two equal splits, the first applied in November 1995 and the second in February 1996.

The following data was recorded: plant height of eight randomly selected plants in the nett plot area of each sub-plot; stem circumference of the same eight plants; cane yield per nett plot, and sucrose yield per nett. Sucrose content was determined using a polarimeter. The measured values of ERC per cent were converted to ERC t/ha. Data collected were subjected to analysis of variance and comparison of means done using the least significant difference test.

Results

A total of 800 mm of rain was received during the 1995/96 agricultural season at Zimbabwe Sugar Association Experiment Station. These rains tailed-off in early February and therefore did not affect the results of the irrigation treatments.

Irrigation and drying-off treatments had a significant effect on cane yield ($P<0.05$), with no interaction between them. There was no significant difference between the crop irrigated at crop factor 1.0 which was the control and that irrigated at crop factor 0.85, while irrigation at crop factor 0.7 significantly decreased cane yield (Table 1). This was due to the differences in cane height and cane circumference (Table 2). Average height of cane plants in the control was significantly greater ($P<0.05$) than that in both restricted irrigation treatments. Likewise, cane plants in

Table 1: The effect of irrigation and drying-off treatments on cane yield.

Irrigation Treatment	Yield (t/ha)	Drying-off Treatment	Yield (t/ha)
Crop factor 1.00	122.6	to 55% depletion	113.3
Crop factor 0.85	120.7	To 60% depletion	115.8
Crop factor 0.70	92.9	To 65% depletion	107.2
LSD (P=0.05)	6.8		6.0
CV%	6.1		6.2

Table 2: The effect of irrigation treatments on cane plant height and circumference at harvest.

Irrigation Treatment	Average Cane Height (m)	Average Circumference (cm)
Crop factor 1.00	1.34	6.45
Crop factor 0.85	1.25	5.80
Crop factor 0.70	0.90	3.75
LSD (P=0.05)	0.08	0.62
CV%	75.80	1.70

the 0.85 crop factor treatment were significantly ($P<0.05$) taller than those in the 0.70 factor treatment. The trend for plant circumference was similar, with the control plants being significantly thicker stemmed than those irrigated at the 0.85 factor which in turn were significantly better than the 0.70 crop factor treated plants.

Drying-off treatments were significantly different in terms of cane yield per hectare (Table 1). Sugar cane dried-off to 65 per cent depletion yielded 107 t/ha which was significantly lower ($P<0.05$) than cane plants dried-off to 60 per cent (116 t/ha) and those of the control 55 per cent (113 t/ha).

Irrigation and drying-off interaction was significant ($P<0.05$) in terms of sucrose concentration as measured by per cent ERC. When sugar cane was irrigated at crop factors of 1.00 and 0.85 there was a significant ($P<0.05$) increase in sucrose content with drying-off to 60 and 65 per cent as compared to 55 per cent available moisture depletion. However, when sugar cane was irrigated at 0.70 crop factor, there was a significant ($P<0.05$) decline in sucrose yield with drying-off to 65 per cent compared to 55 and 60 per cent available moisture. Highest sucrose concentration was achieved with irrigating at crop factor 0.85 and drying-off to 60 per cent available moisture depletion, but this was not significantly different from the treatment combination of 0.85 crop factor and 65 per cent depletion (Table 3). The standard practice of irrigating at crop factor 1.00 and drying-off to 55 per cent moisture depletion and the most restrictive irrigation combination of irrigating at

Table 3: Interaction of irrigation and drying-off treatments in terms of per cent surcrose content (ERC%)

Drying-off Treatments	Irrigation Treatment		
Crop factor	1.00	0.85	0.70
55 per cent depletion	10.39	12.58	12.35
60 per cent depletion	12.21	13.77	12.26
65 per cent depletion	12.60	13.40	10.91
LSD (P=0.05) (Body)	1.31		
CV%	7.20		

crop factor of 0.70 and drying-off to 65 per cent depletion had the lowest sucrose concentrations; these were not significantly different.

There was a significant interaction (P<0.05) between irrigation and drying-off treatments in terms of sucrose yield per hectare. The interaction presented in Figure 1 indicates that if sugar cane has to be irrigated at crop factor 0.70, then this can be dried-off to 60 per cent available moisture depletion which resulted in significantly (P<0.05) more sucrose yield as compared to 65 per cent depletion, but was similar to 55 per cent available moisture depletion. Drying-off to 60 per cent depletion would result in a saving of water compared to the current practice of drying-off to 55 per cent depletion, since drying-off would commence sooner. Irrigating at crop factor 0.85 yielded significantly (P<0.05) more sucrose for all three drying-off treatments than irrigating at crop factor 0.70. Drying-off to a 60 per cent deficit resulted in significantly (P<0.05) more sucrose than drying-off to 55 per cent. The response to a 65 per cent deficit was intermediate but not significantly less than with a 60 per cent deficit. However, drying-off to 65 per cent moisture depletion would result in a larger saving in water. At crop factor 1.00, lowest sucrose yield was achieved with drying-off to 55 per cent depletion. The sucrose yield with this treatment combination, which is the current recommendation was significantly (P<0.05) lower than that with irrigating at 0.85 crop factor and any of the three drying-off treatments (Figure 1). Treatment combinations of crop factor 1.00 and depleting to 60 and 65 per cent performed similarly as the combination of crop factor 0.85 and depleting at 55 or 65 per cent, but were significantly (P<0.05) out-yielded by the 0.85 crop factor and 60 per cent depletion combination.

Discussion

The results of this study clearly indicate that it is possible to manipulate sucrose concentration and hence sucrose yield by restricting the amount of water applied to the sugar cane crop. There are, however, limits to which the crop can be stressed to advantage without affecting economic yield. Under the conditions of this study, highest sucrose concentration and sucrose yield per hectare was achieved by

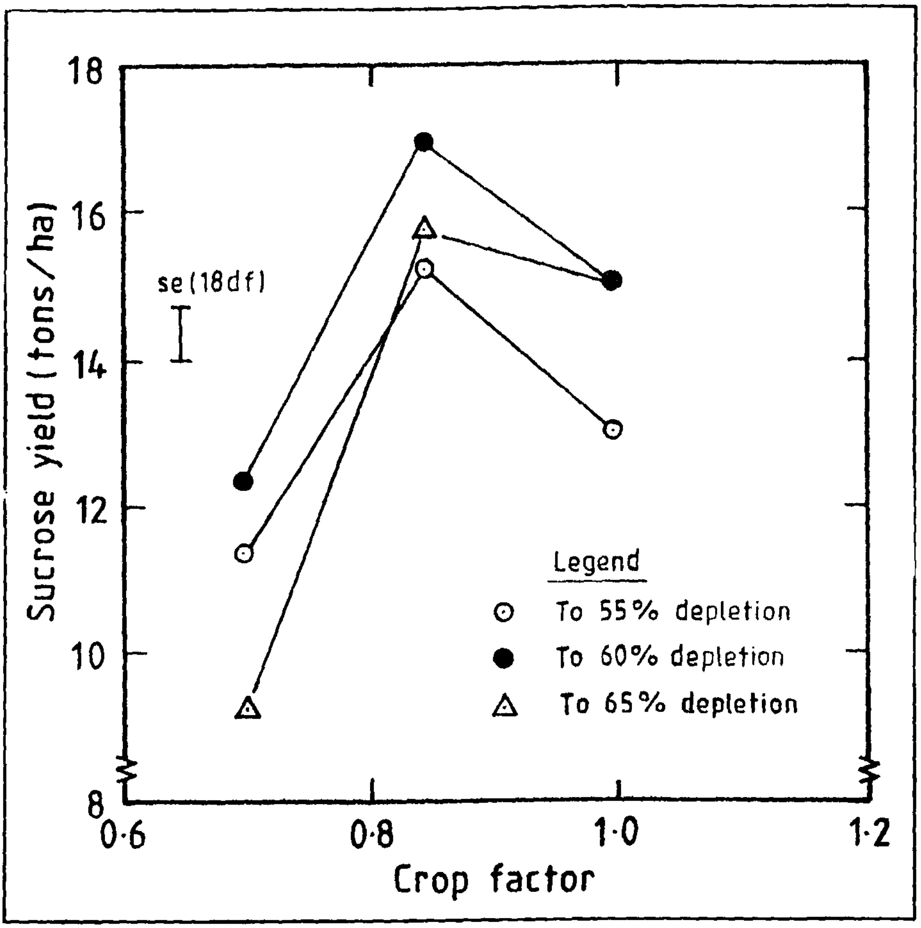

Figure 1: Interaction between irrigation and drying-off treatments on sucrose yield in sugar cane plants.

irrigating at crop factor 0.85 and drying-off to 60 per cent depletion, though results obtained with drying-off to 65 per cent depletion were not significantly lower. Whilst sucrose concentration was better when water was restricted at crop factor 0.70 and drying-off to 55 and 60 per cent depletion compared to current practice (crop factor 1.00 and 0.55 per cent depletion), plant stature and volume of cane harvested was significantly reduced, resulting in a similar sucrose yield per hectare. Severe water restrictions of less than 0.85 crop factor are therefore not recommended. Current irrigation practice in the lowveld appears wasteful of water and reduces potential profits that could be realised by growers.

A higher internal osmotic pressure obtained by accumulating sufficient solutes helps to prevent internal dessication, and apparently makes the cane itself more drought enduring (Gupta, 1967; Briggle, 1994). Sugar cane plants accumulate solutes in the form of sucrose, which is the desired commercial product. Provided the stress is not very severe, cells concentrate sucrose and retain their turgor and therefore continue to grow even when exposed to drought (Vaaida and Wessel, 1979). Irrigating at crop factor 0.85 induced a mild stress which allowed the sugar cane plants to continue growing whilst concentrating sucrose, as evidenced by the data on plant height, cane circumference and sucrose con-centration presented in this paper.

The results obtained in this work are consistent with the observation that ERC values were high during drought years compared to normal years (Farai, 1996). The concept of applying restricted water to sugar cane was successful and could be extended to the field situation by growers. However, growers need to know the total available moisture of the soil before they can successfully extend their drying-off periods. In this trial, drying-off sooner and extending the drying-off period resulted in a saving of 230 mm of water, enough for an extra four cycles of irrigation during the period of active growth. The longer drying-off schedules meant that the last irrigation was applied to the cane crop six weeks before harvest as compared to the normal practice, with no undue effect on sucrose yield.

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REFERENCES

Arnold, H.C. 1993. Plant population in sugar cane production and their effects on sugar yield. *South African Sugar Journal.* **77**:110–117.

Briggle, L.W. 1994. Dryland farming research on sugar cane.Mauritian Sugar Research Institute, Annual Report Bulletin, **690**:56–71.

Department of Metereological Services 1981. *Climate Handbook of Zimbabwe.* 551.582(689.1), Salisbury, April, 1981. 222 pp.

Donald, C.M. 1994. Potential for increased sucrose yield. *Swaziland Sugar Journal* **61**:111–115.

Farai, M. 1996. Drought risk management. Paper presented at seminar on 'Drought management', 13–14 March, 1996, Chiredzi. Zimbabwe Sugar Association. 8 pp.

Gupta, U.S. 1967. *Physiological Aspects of Dryland Farming.* Academic Press, New York. 391 pp.

Vaadia, T.S. and Wessel, N.V. 1979. The physiology of dryland sugar cane. *Cuban Sugar Journal* **27**:19–22.

Zihary, D., Harlan, J.R. and Vardi, A. 1989. Effects of cessation of irrigation on sucrose yield. Zimbabwe Sugar Association Experiment Station, Annual Report Bulletin **180**:59–68.

Zosch, A.N. 1988 Correlation between mois-ture regimes, cane and sugar yield. Zimbabwe Sugar Association Experiment Station, Annual Report Bulletin **179**:49–53.

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